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Art Unit 2644

Amendments to Specification

Please correct numbered paragraph **[0015]** as follows:

a1

-- **[0015]** The invention provides a correlation-based matrix ~~is~~ generated using zero-lag auto and cross-correlations of signals commonly found in echo cancellers. --

Please amend numbered paragraph **[0020]** as follows

a2

-- **[0020]** The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which;-

Figure 1 is a schematic diagram of an echo canceller using LMS Adaptive Filtering; and

Figure 2a is a plot showing the value of det [R] under normal convergence;

Figure 2b is a plot showing the value of det [R] with a path change; ~~and~~

Figure 2c is a plot showing the value of det [R] with double-talk<u>; and</u>

<u>Figure 3 illustrates the process of detecting double-talk</u>. --

Please replace the numbered paragraphs **[0023]**, **[0024]**, **[0029]**, **[0030]**, **[0031]**, **[0033]**, **[0037]**, **[0038]**, **[0039]** with the following new paragraphs as follows. In each case the superfluous μ has been deleted:

a3

-- **[0023]** The preferred embodiment of the algorithm for this patent uses the Normalized-LMS (N-LMS) algorithm. Mathematically, the adaptive filter tap-weight update procedure for the N-LMS algorithm consists of the following three equations

$$\hat{d}[n] = \hat{w}^H[n]u[n]$$

$$e[n] = d[n] - \hat{d}[n]$$

$$\hat{w}[n+1] = \hat{w}[n] + \frac{\mu}{a + \|u[n]\|^2} u[n]e[n]$$

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-- **[0024]** where

$u[n] = R_{IN}$ = echo source signal

$\hat{w}[n]$ = LMS filter coefficients

a3 cont

$d[n] = S_{IN}$ = desired LMS output (echo + double-talk)

$\hat{d}[n]$ = LMS output (estimated echo)

$e[n] = S_{OUT}$ = LMS error signal

μ = LMS step-size parameter

a = A small constant (provides numerical stability). --

-- [0029] Consider two signals, $X_0[n]$ and $X_1[n]$ generated by a linear combination of two real-valued source signals, $S_0[n]$ and $S_1[n]$. Mathematically, this mixing process may be described as

$$X_i = H_{i,0} \cdot S_0 + H_{i,1} \cdot S_1, \text{ --}$$

-- [0030] where $H_{i,j}$ are the mixing coefficients. In matrix form, this may be written as

$$\mathbb{X} = \mathbb{H} \cdot \mathbf{S} \text{ --}$$

a4

-- [0031] where

$$\mathbb{X} = \begin{bmatrix} X_0 \\ X_1 \end{bmatrix}, \mathbb{H} = \begin{bmatrix} H_{0,0} & H_{0,1} \\ H_{1,0} & H_{1,1} \end{bmatrix} \text{ and } \mathbf{S} = \begin{bmatrix} S_0 \\ S_1 \end{bmatrix} \text{ --}$$

-- [0032] A matrix $\mathbb{R}$ is defined as

$$\mathbb{R} = E\left[\mathbf{x}\mathbf{x}^T\right] \text{ --}$$

-- [0033] where E[...] is the statistical expectation operator. $\mathbb{R}$ may be expanded in two ways

$$\mathbb{R} = E\begin{bmatrix} X_0X_0^T & X_0X_1^T \\ X_1X_0^T & X_1X_1^T \end{bmatrix}$$

$$= E\left[\mathbb{H}\mathbf{S}\mathbf{S}^T\mathbb{H}^T\right] \text{ --}$$

a5

-- [0036] The way in which the matrix can be used to perform double-talk and path change detection will now be explained. First, suppose we generate the signal mixtures in using convolutions:

$$\mathbb{X} = \mathbf{H} \otimes \mathbf{S} \text{ --}$$

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-- [0037] Now the terms in the mixing matrix can be vectors. We further impose the condition that $\mathbb{H}$ have the following form:

$$\mathbb{H} = \begin{bmatrix} H_{0,0} & 1 \\ H1,0 & 0 \end{bmatrix} \text{ --}$$

-- [0038] With $\mathbb{H}$ defined in this way, it is now possible to connect the terms in the preceding equations with the parameters available in the echo canceller layout shown in Figure 1. Let

a5 cont

S_0 = echo source signal = $R_{IN} = u[n]$

S_1 = doub   e-talk signal

$H_{0,0}$ = echo path

$H_{1,0}$ = LMS filter coefficients = $\hat{w}[n]$

--[0039] With these definitions, it is apparent that

$$X_o = H_{0,0} \otimes S_0 + S_1 = S_{IN} = d[n]$$

$$X_1 = H_{1,0} \otimes S_0 = \hat{d}[n]$$

As shown in Figure 3, in practising the invention, a first step 10 is performed to generate the correlation-based matrix **R** from X_0 and X_1. A matrix operation 11, for example, forming the determinant is next performed on the determinant, and the result of the matrix operation is then examined at step 12 to detect double-talk and path changes. In the case of the determinant, this is compared with a threshold value. --